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Formation of ellipticals by unequal mass mergers

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Abstract. Collisionless N-body simulations of merging disk-galaxies with mass ratios (η) of 1:1, 2:1, 3:1, and 4:1 have been performed using direct summation with the special purpose hardware GRAPE. The simulations are used to examine whether the formation of elliptical galaxies can be explained in the context of the merger scenario. The photometric, kinematical and isophotal properties of the merger remnants are investigated and turn out to be in very good agreement with observations of giant elliptical galaxies. We conclude that equal mass mergers lead to slowly rotating, anisotropic remnants having predominantly boxy isophotes. Mergers with a mass ratio of 3:1 and 4:1, on the other hand, are fast isotropic rotators with disky isophotes. Projection effects can explain the observed scatter in the kinematical and isophotal properties of elliptical galaxies.

1. Merger model and results

The disk-galaxies are constructed in dynamical equilibrium (Hernquist, 1993) and consist of an exponential stellar disk, a bulge with a Hernquist profile, and a pseudoisothermal dark halo (units as in Hernquist, 1993). The two merging galaxies approach each other on nearly parabolic orbits at a pericenter distance of 2 scale lengths of the larger disk. The large galaxy is realized with 20000 disk particles, 6666 bulge particles and 40000 halo particles, respectively. The smaller galaxy contains $(1/\eta)$ of the mass and of the particles in each component and has a disk scale length of$(1/\eta)^{1/2}$ compared to the more massive galaxy. We tested 14 different relative orientations for every mass ratio. The time integration was performed using the special purpose hardware GRAPE.

After the remnants settled into equilibrium an artificial image of the remnant was created (see also Heyl, Hernquist & Spergel, 1994). Following the definition of Bender, Döberreiner & Möllenhoff (1988) we determined the characteristic isophotal shape $a4_{\rm eff}$, ellipticity $\epsilon_{\rm eff}$, the ratio of major axis rotation and central velocity dispersion, $v_{\rm maj}/\sigma_0$, and the anisotropy parameter $(v_{\rm maj}/\sigma_0)^*$ for 500 random projections of each of the 14 orbital geometries. These values were used to calculate a probability density for a given simulated remnant to be "observed" at a given location in the two dimensional parameter plane, adopting that mergers occur randomly without any preferred relative inclination. Figure 1 shows the result for 1:1, 2:1, 3:1 and 4:1 merger remnants. From these results we conclude that most of the global properties of elliptical galaxies can be explained by a sequence of stellar mergers between disk galaxies of mass ratios

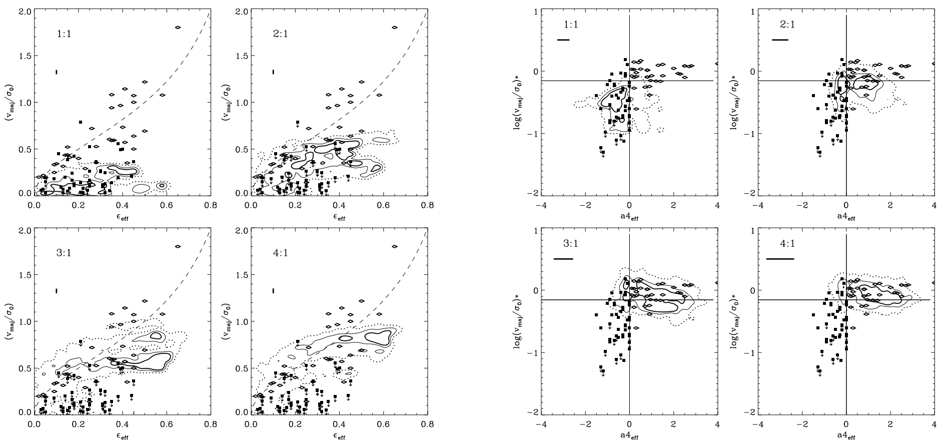

Figure 1. *Left*:The ratio $v_{\mathrm{maj}}/\sigma_0$ along the major axis vs. characteristic ellipticity ϵ_{eff} for mergers with a mass ratio of 1:1, 2:1, 3:1, and 4:1. The contours indicate the 50% (thick line), the 70% (thin line), and the 90% (dotted line) probability to find a merger remnant in the enclosed area. The errors are calculated by applying statistical bootstrapping. The dashed line shows the theoretical value for an oblate isotropic rotator. Black boxes indicate values for observed boxy elliptical galaxies, open diamonds those for observed disky ellipticals (data kindly provided by Ralf Bender). *Right*: Anisotropy parameter $(v_{\mathrm{maj}}/\sigma_0)^*$ vs. $a4_{\mathrm{eff}}$.

between 1:1 and 4:1. 1:1 mergers completely erase the structure of the initial disk. In the 3:1 and 4:1 case the remnants seem to remember their initial state (see Barnes, 1998). In this sense the sequence of mass ratios is a sequence of disk disruption. However, even with 4:1 remnants we fail to reproduce the fastest observed rotators with $v_{\mathrm{maj}}/\sigma_0 > 1$ at one effective radius (Figure 1). Recent observations of fast rotating low luminosity ellipticals (Rix, Carollo & Freeman, 1999) show that the disagreement is even stronger at larger radii (see Cretton, Naab, Rix & Burkert, this conference)

References

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